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ARE FLAME SAFETY LAMPS SUITABLE FOR DETECTING PETROLEUM VAPORS?[1]

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PURPOSE OF INVESTIGATION

Before repairs are made on storage-tanks that have contained crude oil, gasoline, or other distillates of petroleum, it is advisable to be sure that a minimum amount of vapor is present. The examination for vapor should be thorough; it should be made immediately before the tank is entered by the repairmen and periodically thereafter until the men have left the tank.

The flame safety lamp has been suggested as suitable for this service and has been used to some extent by at least one company. In response to inquiries, an investigation was made at the Pittsburgh Experiment Station to determine whether it is safe to use the miner's permissible-type flame safety lamp in gasoline vapors, and their suitability in general for such use.[5]

CONCLUSIONS

The investigation reveals that while permissible miner's flame safety lamps when correctly assembled and intact will not ignite mixtures of gasoline vapor and air, these lamps are not suitable for determination of inflammable vapor content of the atmospheres in and around tanks. The lamps will give unmistakable evidence of the presence of an explosive mixture and will give satisfactory indications to a trained observer in vapor percentages of approximately half of the lower explosive limit. Below this limit the lamps decrease in value as detectors, and at 0.3 per cent and lower the evidence is so small and difficult to observe that it should not be depended upon.

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5 - Paul, J. W., Ilsley, L. C., and Gleim, E. J., Flame Safety Lamps: Bull. 227, Bureau of Mines, 1924, 212 pp.; Paul, J. W., The Use and Care of Miners' Flame Safety Lamps: Miners' Circular 12, Bureau of Mines, 1913, 16 pp.; Ilsley, L. C., Misuse of Flame Safety Lamps and Dangers of Mixed Lights: Miners' Circular 29, Bureau of Mines, 1925, 12 pp.; Ilsley, L. C., Inspection and Assembly of Flame Safety Lamps at the Mine: Reports of Investigations, Serial 2302, Bureau of Mines, 1921, 3 pp.

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Safe practice requires that repairmen do not enter a tank if any trace of gas is present, and since the tests show that the flame safety lamp can not be depended on to give evidence of gas percentages below about 0.3 per cent (and not then except in the hands of one experienced in handling the lamp), it is manifest that the flame safety lamp is not suitable for testing for small percentages of these gases. The proper and efficient detection of petroleum vapors in and around tanks would seem to require a detector that is more accurate and more readily observed than a flame safety lamp. There should be a rugged and portable device especially designed for such use, which would give direct indications at once, and which would be readily visible when readings are being taken at the bottom of a tank. It is believed that such detectors will soon be available to the petroleum industry.

CHARACTER OF TESTS AND GASOLINE USED

The investigation included three series of tests as follows:

1. Safety tests in explosive mixtures moving at approximately 2,500 feet per minute.

2. Safety tests in still and low-velocity explosive mixtures in which the temperatures of the lamp gauzes were measured by means of thermocouples.

3. Tests to determine the behavior of wick flames in various percentages of vapor.

Casing-head, or natural gasoline composed of butane, pentane, and hexane, with pentane predominating, was used.

1. Safety Tests in Moving Mixtures

The tests in moving mixtures were made in the bureau's regular gallery for testing flame lamps. The gasoline was vaporized in a special vaporizer made of a 4-foot length of 8-inch iron pipe with flanged ends. It had valves and pipe connections for mixing steam and the gasoline in proper amounts as they entered the vaporizer, also a series of internal chambers and baffles to separate the condensate from the vapor and allow of its removal.

The velocity of the vapor-air mixture was determined by the amount of air flowing through the test gallery. The mixtures were made by trial and the percentages determined by means of a thermal-conductivity type of gas-analysis apparatus, which on a few occasions was checked by combustion analysis.

A representative lamp of each of the Koehler and Wolf permissible types was used. The tests were made in explosive mixtures of vapor and air and in velocities of approximately 2,500 feet per minute past the lamp. In some of the tests the mixture moved horizontally past the suspended lamp; in others it moved obliquely (45°) down past the suspended lamp; and in others the lighted lamp was thrust up into the horizontally moving mixture. The duration of the tests varied from one to seven and a half minutes, with an average of about two minutes.

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Test Results

These tests, based upon previous tests in methane and air mixtures, were chosen as giving the conditions for maximum burning within the lamps and therefore the greatest heating of the gauzes. Although the inner gauze was perceptibly heated in each test, no ignitions were obtained.

2. Safety Tests in Still and Low-Velocity Mixtures

The tests in still and low-velocity mixtures were made in a steel gallery approximately 6 by 6 by 4 feet. The gallery was equipped with a small mixing fan and a Sirocco blower to direct a stream of the mixture past the lamp. A predetermined amount of the gasoline was vaporized inside the closed gallery.

A Koehler permissible-type lamp was used in these tests. Thermocouples were attached to each gauze as a means of determining the gauze temperatures. A cathetometer mounted outside the gallery, opposite a gallery window, allowed close up observations of the flame and lamp interior.

The lamp was fitted with an internal ignitor by means of which it could be relighted without opening the gallery or removing the lamp.

Test Procedure

The lighted lamp was placed on a stool near the front center of the gallery, and the mixing fan was started; the desired amount of gasoline was then evaporated. The percentages used were 0.0, 1.1, 2.6, 3.3, and 3.9. With each percentage, gauze temperature readings were obtained corresponding to the following velocities of the mixture past the lamp: 0,200, 400, 600, 800, and 1,000 feet per minute. Whenever the lamp was extinguished it was relighted, except in some cases in which no sustained burning could be obtained. In addition to the temperature readings, the behavior of the lamp was observed by means of a cathetometer.

Test Results

The following observations were made:

1. At each percentage of gas in which sustained burning was obtained in the lamp, the greatest temperatures were obtained in very low-velocity movement, below 100 feet per minute, of the mixture past the lamp. At higher velocities the effect of the increase in the quantity of gas burning in the lamp seemed to be more than offset by the increase in loss of heat to the air current, and the gauzes became cooler.

2. Under any condition of velocity the temperature of the gauzes increased with increase in percentage of gas. This, however, was true only up to the lower explosive limit of the mixture, because burning within the lamp invariably ceased when in explosive mixtures.

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3. The maximum gauze temperatures obtained in still mixtures were 324° C. with the inner gauze, and 218° C. with the outer gauze. These temperatures increased to 350 and 300° C. in a velocity of 1,000 feet per minute.

No ignition of a mixture external to the lamp was obtained, and the temperature of the outer gauze was always less than 50 per cent of the temperature necessary to produce an ignition of the vapor mixtures by a lamp gauze.

BEHAVIOR OF LAMP FLAMES IN VARIOUS PERCENTAGES OF VAPOR

Tests in various percentages of vapor consisted of placing or carrying lighted lamps into a test gallery, evaporating the desired amount of the gasoline, and observing the behavior of the flames. The following lamps and equipment were used:

1. Four permissible-type lamps -- Koehler flat wick, Koehler round wick, Wolf flat wick, and Wolf round wick.

2. A 4½-cubic foot steel gallery equipped with paper relief head in case of an explosion.

3. A 1,000-cubic foot glass gallery for check tests in low-percentage mixtures.

4. A cathetometer for observing the flames in the 4½-cubic foot gallery.

5. Thermal-conductivity apparatus for analyzing mixtures.

6. Vacuum sample bottles for combustion analyses.

7. Gas masks for tests in 1,000-cubic foot gallery.

Tests in 4-Cubic Foot Gallery

The gallery was placed in a dark room for observation of low flames. Two and sometimes three lamps lighted with low flames were placed in the gallery directly in front of the observation window. A desired amount of the gasoline was evaporated, and the changes in heights of the gas caps were noted. Samples of the mixture were taken at approximately the same time as the observations. The samples were analyzed directly by means of the thermal-conductivity apparatus or were taken for combustion analysis by means of vacuum bottles broken inside the gallery. Observations were made in various mixtures from 0 to 1½ per cent.

A similar series of tests was made using wick flames approximately seven-eighths inch in height and noting the changes in flame height at each percentage.

Check tests were made in low-percentage mixtures in a 1,000-cubic foot gallery. The gallery was made semidark. The flames were adjusted outside the gallery, and the lamps were then carried into the gallery by the observers, who

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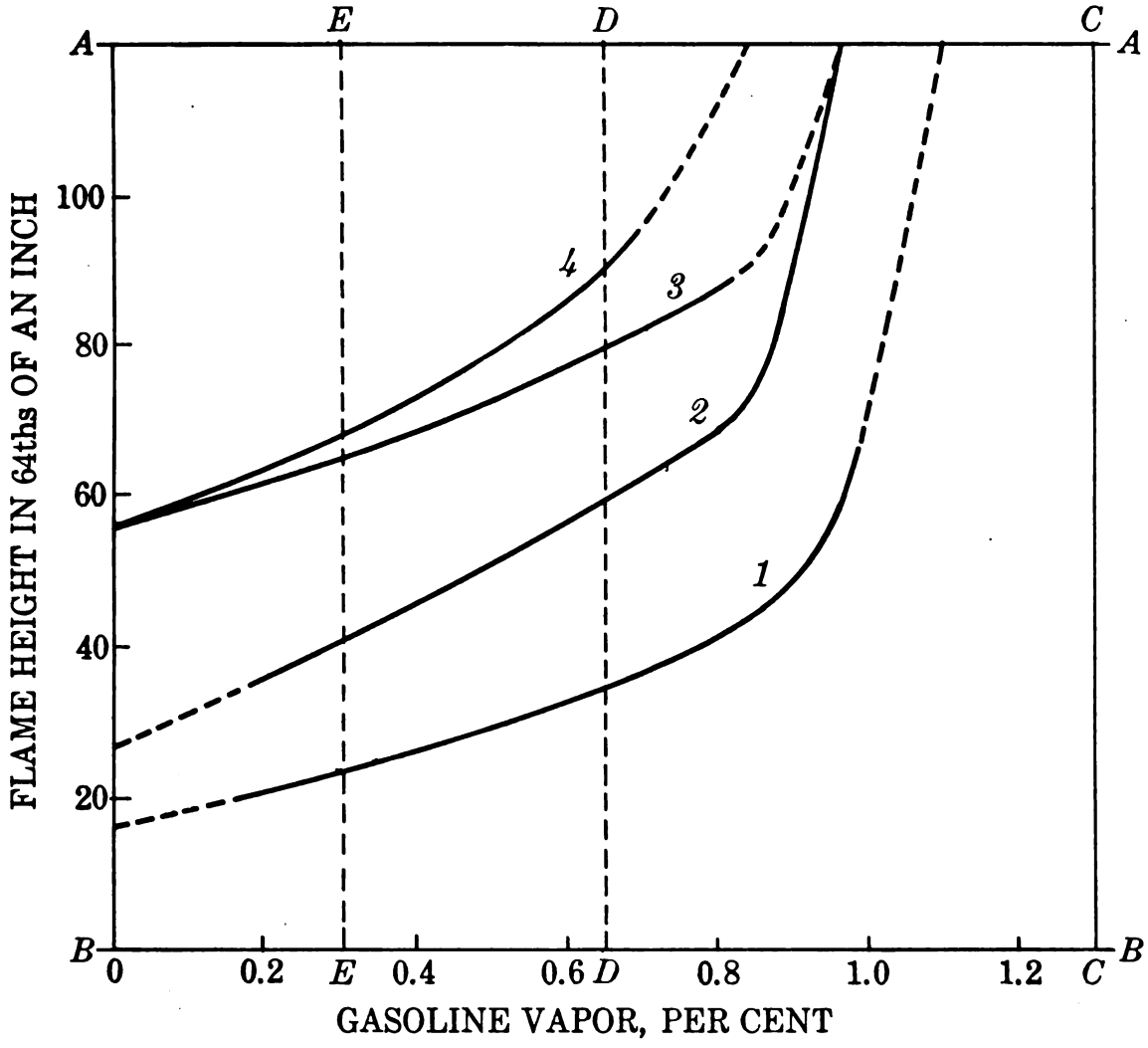

Figure 1.- Height of flames of round and flat wick lamps in casing-head gasoline vapor and air mixtures. Curve 1, round-wick lamp, low testing flame; curve 2 - flat-wick lamp, low testing flame; curve 3, round-wick lamp, high (7/8 inch) testing flame; curve 4, flat-wick lamp, high (7/8 inch) testing flame

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wore gas masks. After observing the change in flame height of each lamp, the flame was lowered until just a trace of yellow flame was visible, and the height of the gas cap was noted.

Tests were made in gas mixtures of zero to 0.8 per cent, using two flat-wick and two round-wick lamps.

Test Results

Figure 1 shows the variations in heights of flames of both round-wick and flat-wick lamps, with percentage of gasoline vapor. Curves 1 and 2 show the average values obtained with the round-wick and flat-wick lamps with their flames adjusted in air until just a trace of yellow tip remained. Curves 3 and 4 are the corresponding values obtained with flames adjusted in air to seven-eighths inch.

The line A-A represents the top of the lamp glass; the zero line B-B represents the top of the wick tube and therefore the bottom of the flame; line C-C represents the lower explosive limit of the gasoline vapor used in this investigation. This value was obtained by determining the minimum concentration that could be ignited in the gallery.

The line D-D represents one-half the lower explosive limit percentage value. The line E-E is approximately the maximum concentration into which men may enter without being equipped with gas masks.

In the low percentages, low-flame readings were impossible; in the higher concentrations the high flame of both types of lamps and the low flame of the round-wick lamps became too unstable to permit definite readings. These parts of the curves are therefore shown in short broken lines.

DISCUSSION OF RESULTS

An investigation of the behavior of a flame safety lamp in vapor and air mixtures was made by Wilson and Wilken,[6] who used a flat-wick Koehler lamp. Their vapor, however, was hexane, whereas that used in the bureau's tests was mostly pentane. They used a smaller gallery, of approximately 0.7-cubic foot volume, as compared with the 4½ and 1,000-cubic foot galleries used in the bureau's tests.

It is interesting to note that in both investigations the maximum rise in height of the long or lighting flame was about one-half inch.

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6 - Wilson, R. E., and Wilken, R. E., Use of Koehler Safety Lamp in Testing Tanks for Combustible Gases or Vapors: Industrial and Engineering Chemistry, vol. 16, 1924, pp. 1154-1156.

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The chief difference in the results obtained was in the relative elongation of flames of different heights. For example: Whereas between the vapor percentages 0.32 and 0.8, the difference in rise of the three-eighths inch and seven-eighths inch flames was about 40 per cent in the bureau's tests, the rise of the seven-eighths inch flame being greater, Wilson and Wilken obtained a difference of more than 300 per cent for these flames. Much of this difference may be due to reading the short flames under different conditions. The low flame in low-percentage mixtures does not have a well-defined top; consequently it is difficult to see and takes longer to observe.

Part of the present tests were made in a large gallery into which the observers could carry the lamps. Under this condition it is possible, by moving the lamp and causing relative motion between it and the flame, to detect the real top of the gas flame more readily.

The bureau's tests indicated that the superiority of one flame over another was not so much in the relative change in heights as in the visibility and stability of the flame. A high or full luminous flame is more easily seen than a low flame and is much less liable to be extinguished by bumping the lamp. A low flame can be adjusted in the mixture to be examined and no correction need be applied. A low flame is thus independent of changes in the flame height that may occur as the lamp is being carried into or out of a tank. The tests showed that in concentrations up to 0.3 per cent, a lamp of either type used in this investigation is unsatisfactory as a detector because a low-flame gas cap does not have a well-defined top, and in general does not have enough body to be readily seen. A high flame has such a small(one-eighth inch) change in height at this low percentage that it is difficult to observe.

The rise of either the short or long flame in a percentage of half the lower explosive limit was about one-fourth inch for the round-wick lamps and three-eighths inch for the flat-wick lamps.

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